LEFT-HANDEDNESS IN TWINS

PAUL T. WILSON AND HAROLD E. JONES[1]
Institute of Child Welfare, University of California, Berkeley, California
Received March 26, 1932

INTRODUCTION

WEITZ (1925), DAHLBERG (1926), and NEWMAN (1928b) have called attention to the apparently high percentage of left-handedness in identical twins. Their findings are summarized in the following table:

TABLE 1

INVESTIGATOR	CRITERION OF LEFT-HANDEDNESS	TYPE OF TWIN			
		IDENTICAL		FRATERNAL	
		NUMBER OF INDIVIDUALS	PERCENT L	NUMBER OF INDIVIDUALS	PERCENT L*
WEITZ	Not stated	36	25.0±4.9	..	..
DAHLBERG	Asking "with which hand the person in question throws a stone, or cuts his bread."	138	14.5±2.1	256	7.0±1.1
NEWMAN	Relative efficiency of the two hands in tapping (wrist, and finger).	100	12.0±2.2	100	6.0±1.6

* In this table, and those following, the "L" percentages include only the cases of distinct left-handedness; they do not include the relatively few cases of ambidextrous or partially left-handed.

WEITZ offered the opinion that his figures indicated more than an accidental association between monozygotism and left-handedness, but he attempted no theoretical explanation. DAHLBERG emphasized the fairly normal prevalence of left-handedness in his dizygotic population, and suggested that the excess percentage of left-handedness among the identical twins could be due to reversal of asymmetry in a certain proportion of monozygotic pairs, such that one member of the pair (after division of the embryo) presents characteristics in mirror reverse of the original embryo.

This assumes, of course, a hereditary basis for handedness, with an additional factor (involving mirror reversal) which is not necessarily hereditary. NEWMAN has carried the theory a step further by relating mirror

[1] The authors gratefully acknowledge the assistance of Professor S. J. HOLMES in the organization of this report.

reversal to the stage of development at which twinning occurs. In an earlier publication (NEWMAN 1923) he had proposed three methods by which monozygotic twins may originate: (A) the division of a blastoderm into two separate blastoderms, each of which develops an embryo, (B) double gastrulation on a single blastoderm, (C) longitudinal fission of a single embryonic axis (at a late stage in gastrulation), producing bilateral halves which regenerate and produce separate embryos. Twinning by the first two methods is known to occur in various infra-human species, and probably also in man. Twinning by the third method is challenged by STOCKARD and others on grounds which need not be considered here. It is this third method which has been utilized by NEWMAN (1928b) as an explanation of reversed asymmetry phenomena. According to this theory, twinning by the first two methods will produce markedly similar twins with the same type of axiate organization, or if reversed asymmetry is present, there will be a tendency for each embryo to regulate back to the original asymmetry of the undivided zygote; twinning by the third method will produce twins that are less similar in general organization but with a tendency to reversed asymmetry in handedness, crown whorl, and other unilateral characteristics. This may be so marked that one twin may show only right-handed expressions for certain characters on *both* sides of the body, the other twin only left-handed expressions.

It may be noted that this theory calls for a prevalence of left-handedness among the dizygotic which will be markedly less than that among the monozygotic, and which will approach that of the single born. Such is, in fact, the case with both DAHLBERG'S and NEWMAN'S data. But certain other data are available which call this finding in question and which appear to demand further investigation of the problem. SIEMENS (1924, p. 65) and VERSCHUER (1927) have obtained the results listed in table 2.

The percentage of left-handed among the fraternal twins is here markedly in advance of what would be expected in an unselected population of single born. Further evidence of the same nature is furnished by LAUTERBACH (1925), who failed to classify his cases as identical and fraternal but who found among 126 twins from opposite-sex pairs 12.7 percent left-handed (on the criterion of the hand employed in throwing), while among 276 same-sex twins, only 8.7 percent were diagnosed as left-handed.

These discrepant results may depend partly on the varying reliability and validity of the methods of identifying the left-handed. In the case of the European investigators, evidence is frequently lacking that the classification was made in a sufficiently objective and standardized manner. NEWMAN'S classification, based upon tapping, may be called in question

in view of recent results by OJEMANN (1930) who finds that the tapping test, taken alone, is inadequate for separating the left-handed from the ambidextrous and right-handed. A developmental criterion, based upon habitual behavior and subjective preference (such as the "throwing hand" test) is also inadequate for the diagnosis of individuals, but for the characterization of groups it may be expected to give results of greater significance than in the case of simple tests based upon quantitative performance in which differences in motivation may conceal true differences in efficiency.

TABLE 2

INVESTIGATOR	CRITERION OF LEFT-HANDEDNESS	TYPE OF TWIN			
		IDENTICAL		FRATERNAL	
		NUMBER OF INDIVIDUALS	PERCENT L	NUMBER OF INDIVIDUALS	PERCENT L†
SIEMENS	(Not stated, but "the left-handedness was in most cases very pronounced.")	102	10.9±2.1	62	27.4±3.8
VERSCHUER	Not stated*	158	15.8±2.0	76	13.2±2.6

* In a direct communication Doctor VERSCHUER says, "I asked the individual which hand he usually used for doing certain tasks and some individuals were then asked to demonstrate by cutting paper with scissors, driving a nail with a hammer, throwing a stone or shuffling cards."

† DAHLBERG (1926, p. 183) says, "In a later work 1924c, SIEMENS gives the figure 16.4±3.6 percent left-handed among the dizygotic."

(JONES [1931, p. 135] has reported dextrality ratios on five tests for a pair of twins. The average results tally with other measures of handedness in these twins, but single tests give widely differing indications.) A further consideration is that the prevalence of left-handedness may vary according to age (JONES 1931) and sex (WILSON and DOLAN 1930); hence these factors should be controlled in a comparison of the various studies and of the two types of twins. Another major deficiency of these studies is that they lack a control group of single born, and hence we do not know how to interpret their prevalence data in relation to a strictly comparable normal group.

In one later study (HIRSCH 1930), results have been obtained which are somewhat in agreement with the data of NEWMAN and DAHLBERG, although the twins are divided into "similar" and "dissimilar" like-sex pairs rather than classified as identical and fraternal. Of 116 dissimilar twins (individuals) 6.0 percent were left-handed while of 86 similar twins an uncommonly high incidence of 20.9 percent was recorded. Criteria for deter-

mining handedness were not stated. Nor is it stated whether the classification of similar and dissimilar twins was made independently of the data on reversed asymmetry. HIRSCH'S twins had a median age of approximately 11 years, somewhat younger than that of the majority of other investigators.

The present investigation, conducted as a part of a series of studies on twins, is based upon 386 twins and 521 single born in the school systems of Oakland, Berkeley and San Francisco. The comparative age and sex data are presented in table 3.

TABLE 3

TWINS	NUMBER AND AGE OF INDIVIDUALS		STANDARD DEVIATION*
	NUMBER OF INDIVIDUALS	MEAN AGE IN YEARS*	
Identical			
Males	62	14.88±.18	1.48±.13
Females	78	15.46±.19	1.73±.13
Total	140	15.20±.13	1.64±.09
Fraternal			
Males	98	14.72±.16	1.61±.11
Females	148	15.27±.15	1.88±.10
Total	246	15.20±.10	1.73±.07
Single born			
Males	277	15.20±.09	2.18±.06
Females	244	15.17±.08	1.95±.06
Total	521	15.18±.06	2.07±.04

* For the data on twins the probable errors are based upon the number of *pairs* in each group.

METHOD OF SAMPLING

In an attempt to locate a representative sample of twins in the age range of 10 to 20 years, 19 junior and 16 senior high schools were canvassed.

The twins were located in each school through the principal's office. Particular effort was made to locate not only those twin pairs that were together in a class, but also pairs of which the two members were in different grades or different schools. A previous report (WILSON and JONES 1931) has described a similar sampling of twins, covering a wider age range.

The single born group used as a control was recruited from one junior and one senior high school. Both schools have a large enrollment and are considered representative of the school population from which the twin

sample was drawn; an unselected sample was taken in these schools in all grades from the seventh through the twelfth.

CLASSIFICATION OF TWIN TYPE

Individual examinations of the twins gave opportunity to classify each pair as to type (identical or fraternal). The criteria used are the same as described in previous studies by the authors (WILSON and JONES 1931), and are based on those suggested by SIEMENS (1927), DAHLBERG (1926), and NEWMAN (1928a). This method is based upon the theory that if two members of a pair closely resemble each other in a number of characteristics, each of which is largely and independently determined by genetic factors, there is a very high probability that the two individuals have the same germinal make-up and are therefore of monozygotic origin. In this study, determination of the type of each pair was made by conference between the examiners at the time of the examination. If there remained a doubt which closer examination could not dispel, the pair was classified as "undetermined." In this study as in others using the same method, the large majority of pairs were very readily classified in one group or the other. There remained, however, fifteen pairs (8 percent of the total) which the examiners conservatively classified as "undetermined."

In another study undertaken a few months subsequently, a third worker (J. BURKE) had occasion to interview and classify 80 of these same pairs. He used the same criteria but his diagnosis in each case was made without knowledge of our classification. In only three cases did his grouping disagree with ours: two pairs that we classed as "undetermined" he listed as fraternal, and another pair classed as "undetermined" he called identical. In no case was a pair shifted from identical to fraternal or *vice versa*. Consistency of classification is not necessarily proof of validity; there is, however, a high degree of certainty that errors in classification have not been sufficiently numerous to affect group comparisons.

THE CLASSIFICATION OF ASYMMETRY TRAITS

The data on asymmetry traits of the twins were included in an examination in which anthropometric and other physical data were obtained. The anthropometric measurements were omitted in the case of the single-born controls, but in other respects the same method was employed.

1. The child was asked, "Which hand do you write with?" His answer was noted as R or L on the handedness schedule.

2. He was then asked, "Which hand do you throw a ball with?" If there was any apparent uncertainty in the answer the child was asked to demon-

strate. A number of individuals were found who reported, and demonstrated, that they threw with either hand with about equal facility. These were marked RL (see table 4).

3. The dominant eye was determined by having the child look through a ring (both eyes open) at a fixed object between the child and the examiner. Three trials were given; in case the child showed an initially unstable reaction, additional trials gave him an opportunity to stabilize on either R or L preference. When a shifting preference was maintained through more than six trials, the child was recorded as "?" in this trait. In nearly every case at the time the test was being made the child was quite unaware of which eye he was using, or that his fixation was uniocular.

4. Crown whorl was in most cases readily determinable as clockwise or counterclockwise at the same time that the cephalic measurements were being taken. In a few individuals considerable care had to be exercised to make the correct classification, and occasionally through considerations of time or cooperation the diagnosis had to be left as "?" (see footnote, table 6). A few instances of double crown were noted.

RESULTS

TABLE 4

Handedness, by individuals (throwing hand).

	MALES		FEMALES		TOTAL	
	NUMBER OF INDIVIDUALS	PERCENT L	NUMBER OF INDIVIDUALS	PERCENT L	NUMBER OF INDIVIDUALS	PERCENT L
Identical*	62	11.3±2.7	78	10.3±2.4	140	10.7±1.8
Fraternal (same-sex)	44	11.4±3.2	94	10.6±2.2	138	10.9±1.8
Fraternal (opposite-sex)†	54	14.8±3.3	54	9.3±2.6	108	12.0±2.2
All fraternal	98	13.3±2.4	148	10.0±1.7	246	11.4±1.4
All twins	160	12.5±1.8	226	10.0±1.4	386	11.1±1.1
Single born‡	277	6.9±1.1	244	6.2±1.1	521	6.5± .7

* Three and two tenths percent of the identical males and one and four tenths percent of the identical females were classified as RL (dextro-sinistral).

† One and nine tenths percent of the opposite sex males were RL.

‡ Seven tenths percent of the single born males and one and two tenths percent of the single born females were RL. The percentage of left-handed among the single-born is slightly higher than that which has been reported in a number of prevalence studies; Miss H. E. NEALL (unpublished data), however, in a very thorough canvass of over 800 cases in a Berkeley kindergarten population, found the incidence of left-handedness to be 6.5 percent; and QUINAN (1930) in a recent report on over 1000 University students found 7.6 percent to be left-handed.

TABLE 5

Handedness, by pairs (throwing hand)

	MALES		FEMALES		NUMBER OF PAIRS	TOTAL	
	PERCENT R-L	PERCENT L-L	PERCENT R-L	PERCENT L-L		PERCENT R-L	PERCENT L-L
Identical	22.6±5.1	0	15.4±3.8	2.6	70	18.6±3.1	1.4
Fraternal (same-sex)	22.7±5.8	0	17.0±3.7	2.1	69	18.8±3.2	1.4
All (same-sex)	22.6±3.9	0	16.3±2.7	2.3	139	18.7±2.3	1.4
Fraternal (opposite-sex)	..	..	..	..	54	20.4±3.7	1.9
All fraternal	..	..	..	..	123	19.5±2.4	1.6
All twins	..	..	..	..	193	19.2±2.0	1.6

Our data for traits other than throwing hand (table 6) show no reliable differences between groups of identical and fraternal twins or between the twins and the single-born controls.

Data from other studies of crown whorl show very conflicting results as illustrated by the following figures:

NEWMAN (1928b) 94 individuals from identical pairs 24.4±3.0 percent "L" whorl
NEWMAN (1928b) 96 individuals from fraternal pairs 4.1±1.4 percent "L" whorl
VERSCHUER* (1931) 234 individuals from identical pairs 25.6±2.0 percent "L" whorl
VERSCHUER* (1931) 152 individuals from fraternal pairs 26.3±2.4 percent "L" whorl
LAUTERBACH (1925) 256 individuals from like-sex pairs 6.6±1.1 percent "L" whorl
LAUTERBACH (1925) 116 individuals from unlike-sex pairs 18.1±2.4 percent "L" whorl
LAUTERBACH (1927) 1008 individuals single-born "normal" 18.1±0.9 percent "L" whorl

* No mention is made of double crowns. In all other studies an additional small percentage of twins of both types had double crowns.

No comparable studies are known of "eyedness" in twins. PARSONS (1924), using a "manoptoscope" in a study of 877 school children, found that about one third were "left-eyed." QUINAN (1930), in a study of 1000 male college students, found that 22.5 percent sighted a pistol with the left eye.

With reference to the handedness data, it is clear that the tables for the throwing hand (tables 4 and 5) give a clearer picture of "natural" preference than the data on writing (table 6), for in the latter function, home and school influences combine to encourage left handed children to use the right hand. The outstanding fact about these percentages on the throwing hand is that *both* monozygotic and dizygotic twins agree in showing a higher incidence of left-handedness than occurs in a representative population of single born.

TABLE 6

Prevalence of other types of asymmetry.

TRAITS	IDENTICAL			SAME-SEX FRATERNAL			OPPOSITE-SEX FRATERNAL	ALL FRATERNAL	ALL TWINS	SINGLE BORN		
	MALE N=62	FEMALE N=78	TOTAL N=140	MALE N=44	FEMALE N=94	TOTAL N=138	N=108	N=246	N=386	MALE N=277	FEMALE N=244	TOTAL N=521
	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's	PERCENT L's
Writing hand	8.1	3.8	5.7±1.3	4.5	5.3	5.1±1.3	5.6±1.6	5.3±1.0	5.5±0.8	5.4±0.9	2.9±0.7	4.1±0.6
Dominant eye*	25.8	46.1	37.0±2.8	38.0	37.0	37.4±2.8	30.0±3.0	35.6±2.1	36.1±1.7	32.5±2.0	36.9±2.1	34.6±1.4
Crown whorl*	15.3	17.6	16.8±2.2	15.0	12.9	13.6±2.0	23.8±2.8	18.0±1.7	17.6±1.3	18.4±1.6	19.6±1.7	18.9±1.2

* Individuals classified as "?" for the given trait (see text) were not considered in computing these percentages; this lowered the N slightly for some groups: for "dominant eye" there were 7 fraternal and 6 single born, for "crown whorl" there were 9 identical, 12 fraternal and 19 single born classed as "?." About 3 percent of the fraternals and 1 percent of the identicals had double crowns.

DISCUSSION

Several alternative explanations may be offered for these findings:

1. The excess percentage of left-handed among monozygotic twins (as compared with single born individuals) may be due chiefly to reversal of asymmetry, as proposed by DAHLBERG and NEWMAN. A similarly increased percentage among dizygotic might then involve other factors not yet formulated. Such an explanation would be of greater complexity than a single theory applicable to both types of twins. Inasmuch as in our study the two types of twins share substantially the same increments of left-handedness, as compared with the single born, it is natural to look for a common explanation of this phenomenon. It may be noted that our data concerning hair whorl and eyedness are not in support of the NEWMAN-DAHLBERG theory, for in these traits twins and single born show no significant differences. If the excess left-handedness in twins is due to embryonic reversal of asymmetry, it is a matter of surprise to find that in other respects no increase of reversed asymmetry is registered. We are unable to account for the discrepancy between our results and NEWMAN'S, except possibly on the assumption that his method of sampling slightly favored the selection of identical twins possessing striking characteristics as to reversed asymmetry.

2. It has been suggested by LAUTERBACH that reversal of asymmetry in the embryo may be responsible for the increase of left-handedness both in identicals and fraternals, a left-handed fraternal twin being one of two surviving members of dizygotic triplets (or quadruplets). But if left-handedness is as frequent among fraternals as among identicals, then *every* fraternal pair contains a surviving member of a monozygotic pair. There is no escape from such a conclusion, except by making extraordinary assumptions as to differential prenatal mortality of twins. Furthermore, if we carry this theory to its next logical step, we would assume that left-handed single born are the surviving members of monozygotic twin embryos; this would also lead us into improbabilities, for since less than 2 percent of all left-handed children are members of living monozygotic twin pairs, we would have to assume a prenatal mortality affecting one member of the pair in over 98 percent of RL monozygotic pregnancies.

3. Left-handedness may be hereditarily determined, the factors for twinning being linked with factors for sinistrality. This theory would assume a common hereditary basis for the two types of twins, and JORDAN (1914) and others have accumulated some evidence in support of such a view. The investigation of family lines, with especial reference to familial strains of

twins and of left-handed individuals, may throw some light on this problem, if data can be assembled from sufficiently large populations. In our group of 70 identical pairs, only one pair is L-L, and in the group of 123 fraternal pairs two pairs are L-L. This population is too small to compare identicals and fraternals in a characteristic affecting so small a number of pairs. However, when the percentage of L-L pairs is computed for six of the most important studies in the literature, a total of 688 pairs, it is found that 4.5 percent of the identicals and 1.7 percent of the fraternals are L-L. This is similar to what would be expected on the assumption that hereditary tendencies exist toward left-handedness. For if X/100 is the incidence of hereditary left-handedness among the single born, then this should be the incidence among zygotes destined to form plural embryos, and it should also be the incidence of L-L pairs among the monozygotic (except as reduced by tendencies toward mirror reversal or by differential mortality). But among the dizygotic, the expected incidence of L-L pairs would from the outset be $(X/100)$.[2]

4. The position of the foetus in the uterus may affect development of the functional predominance of one hand. Twins of either type are much more crowded, and foetal movements more restricted than among the single born. In the case of the single born, the foetus usually lies with its long axis more or less parallel to that of the mother and with its head downward. At birth about 96 percent are presented head first (WILLIAMS 1930). In twins the position is much more varied: they may both lie with their long axes either parallel or at right angles to that of the mother; the two heads may be together or they may be opposite. The frequency of the latter position is indicated by the fact that about 31 percent of individual twins are delivered breech first as compared with only 3 percent of single born children (WILLIAMS 1930). Since twins of both types undergo the crowding and other changes of position due to the "abnormal" conditions accompanying twinning in man the effect would tend to be similar on the two classes of twins. In this way the similar handedness data for both types would be accounted for. The authors are not prepared to enter into a detailed discussion of the relation of foetal position to the phenomena of handedness, but the possibility of such a relationship seems to deserve consideration.

SUMMARY

Handedness data were secured for 386 individual twins of high school age, and also for a control group of 521 single born. The twins were diagnosed as of fraternal or identical type, and the data for each type were

compared with those for the single born. The traits studied were: hand used for throwing, hand used for writing, dominant eye, and crown whorl. The hand used for throwing was considered the best measure of "natural" handedness. The more significant findings were as follows:

1. With "throwing hand" as the criterion of handedness, the incidence of left-handed individuals among the twins was from 10.7 ± 1.8 to 12.0 ± 2.2 percent depending on the group. Among the single born the incidence was reliably lower, 6.5 ± 0.7 percent.

2. Although the difference was never reliable, the percentage for the boys was consistently higher than that for the girls. Some importance attaches to the question as to whether this excess is the same as among the single born, or whether it is increased by those factors which increase left-handedness among twins. More cases will be necessary before this question can be answered satisfactorily.

3. There was no reliable difference between identical or fraternal nor between the like-sexed and the unlike-sexed groups.

4. Between 18.6 and 20.4 percent of the *pairs* of each group contained one left-handed member. There was no reliable difference between the identical and fraternal nor between the like-sexed and unlike-sexed pairs.

5. For "writing hand" the twins showed an unreliably higher percentage than the controls (5.5 ± 0.7 percent *versus* 4.1 ± 0.6 percent). For the other traits of asymmetry there was no indication of a significant difference between the identical and fraternal, the like-sexed and unlike-sexed groups, nor between the twins and the single born.

6. Our data on handedness (using throwing hand as the criterion) agree rather well with data obtained by SIEMENS, VERSCHUER and LAUTERBACH, but differ from the data of DAHLBERG, NEWMAN and HIRSCH. The discrepancies may depend partly on variations in the methods of identifying the left-handed, as well as on factors affecting the selection of twins.

7. No adequate explanation of the factors determining handedness in twins can be formulated until more complete agreement exists concerning the true incidence of the different kinds of asymmetry among the different types of twins. As a next step it seems desirable to work with a greatly increased number of cases (twins and single-born controls) and to develop a more comprehensive standardized method of diagnosing asymmetries.

LITERATURE CITED

DAHLBERG, G., 1926 Twin births and twins from a hereditary point of view. Stockholm: Bokförlags-A.-B. Tidens Tryckeri.

HIRSCH, N. D. M., 1930 Twins, heredity and environment. Cambridge, Massachusetts: Harvard University Press.

JONES, H. E., 1931 Dextrality as a function of age. Exp. Psychol. **14:** 125–143.
JORDAN, H. E., 1914 Hereditary left-handedness with a note on twinning. J. Genet. **4:** 79–81.
LAUTERBACH, C. E., 1925 Studies in twin resemblances. Genetics **10:** 525–568.
LAUTERBACH, C. E., and KNIGHT, J. B., 1927 Variation in whorl of the head hair. J. Hered. **18:** 107–115.
NEWMAN, H. H., 1923 Physiology of twinning. Chicago, Illinois: University of Chicago Press.
1928a Studies of human twins. I. Methods of diagnosing monozygotic and dizygotic twins. Biol. Bull. **55:** 283–297.
1928b Studies of human twins. II. Asymmetry or mirror imaging in identical twins. Biol. Bull. **55:** 298–315.
OJEMANN, R. H., 1930 Studies in handedness. I. A technique for testing unimanual handedness. J. Educ. Psychol. **21:** 597–611.
PARSON, B. S., 1924 Left-handedness. New York: Macmillan Co.
QUINAN, C., 1930 Principal sinistral types. Arch. Neurol. Psychiat. Chicago **24:** 35–47.
SIEMENS, H. W., 1924 Die Zwillingspathologie. Berlin: Julius Springer.
1927 The diagnoses of identity in twins. J. Hered. **18:** 201–209.
VERSCHUER, O. VON., 1927 Der Vererbungs biologische Zwillingsforschung. Ergebn. Inn. Med. Kinderhlk. **31:** 35–120.
1931 Ergebnisse der Zwillingsforschung. Verh. Ges. fur Physische Anthropologie. **6:** 1–65.
WEITZ, W., 1925 Studien an eineiigen Zwillingen. Z. klin. Med. **101:** 115–154.
WILLIAMS, J. W., 1930 Obstetrics, New York: D. Appleton and Co.
WILSON, M. O., and DOLAN, L. B., 1930 Handedness and ability. Amer. J. Psychol. **43:** 261–268.
WILSON, P. T., and JONES, H. E., 1931 A study of like-sexed twins. I. The vital statistics and familial data of the sample. Human Biol. **3:** 107–132.